Technical Report

United States Army
Belvoir Research, Development, & Engineering Center
Fort Belvoir, Virginia 22060-5606

Report 2469

Stressed Fabric Abrasion Test Procedure for Urethane Coated Fabric Fuel Tanks

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Report Date: June 1988

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS None
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution unlimited.
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) No. 2469	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION Materials, Fuels and Lubricants Dir. Rubber and Coated Fabrics Research Grp. 6b. OFFICE SYMBOL *(If applicable)* STRBE-VU	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS *(City, State, and ZIP Code)* Belvoir RD&E Center Fort Belvoir, VA 22060-5606	7b. ADDRESS *(City, State, and ZIP Code)*
8a. NAME OF FUNDING/SPONSORING ORGANIZATION 8b. OFFICE SYMBOL *(If applicable)*	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS *(City, State, and ZIP Code)*	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. / PROJECT NO. / TASK NO. / WORK UNIT ACCESSION NO.

11. TITLE *(Include Security Classification)*
Stressed Fabric Abrasion Test Procedure for Urethane Coated Fabric Fuel Tanks (U)

12. PERSONAL AUTHOR(S)
Pat Butler and Dave Flanagan

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT *(Year, Month, Day)*	15. PAGE COUNT
Final	FROM Apr 87 TO Apr 88	June 1988	14

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18. SUBJECT TERMS *(Continue on reverse if necessary and identify by block number)*
FIELD	GROUP	SUB-GROUP	Abrasion, Urethanes, Collapsible Tanks

19. ABSTRCT *(Continue on reverse if necessary and identify by block number)*

This report details investigations conducted and results obtained in efforts to develop a test procedure for measuring the effects of abrasion under stress in urethane-coated fabric tanks.

The Rubber and Coated Fabrics Research Group, Materials, Fuels and Lubricants Directorate, Belvoir Research, Development and Engineering Center, prepared all samples from material submitted by coated fabric suppliers, performed all tests, and documented results.

Four different urethane materials were tested on the Taber Abrader which was modified to test the fabric under stress. The urethanes showed a marked decline in the ability to withstand abrasion while under stress.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT [x] UNCLASSIFIED/UNLIMITED [x] SAME AS REPORT [ ] DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL Pat Butler	22b. TELEPHONE *(Include Area Code)* 703-664-1127 22c. Office Symbol STRBE-VC

DD Form 1473, JUN 86 *Previous editions are obsolete.*

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SECTION I. BACKGROUND

The Army began using collapsible fuel tanks in quantity during World War II. A system was needed to temporarily hold fuel being off-loaded at the front until its use, and a rubber-coated tank was simpler to set up than a bolted steel tank. These early tanks were built along the same lines as a bias ply tire with multiple plies vulcanized into a fuel resistant rubber liner. They were very bulky and hard to handle by today's standards, but the military found the system more desirable than the previously used bolted steel tanks.

During the Vietnam war, weaknesses became evident in the tank design. The empty tank's weight and size made if very difficult to transport into the field. Its black color did not blend into the background and, by absorbing the sunlight, caused the fuel to overheat. A new type of holding tank was needed with the following requirements: lightweight for easy transport to forward areas and a light color that would blend into the environment. Longevity was not a consideration. The new tank was constructed of a single ply fabric coated with either a nitrile or a thermosetting urethane. The coated fabric was seamed together, forming a pillow-shaped tank that was easily transportable and capable of storing fuel for short periods of time. The tank was still considered an expendable item during tactical maneuvers.

In today's austere fiscal atmosphere, items having the price tags of collapsible tanks the are unexpendable. The Army's current direction is toward a lightweight fuel tank having a 20-year shelf life and a 5-year service life. Except for a major material shift to thermoplastic urethanes, no major changes to the tank's design are planned. The new material must better withstand the effects of the elements and abuse.

A problem with trying to improve the material used in collapsible tanks was the unavailability of long term field data; therefore, laboratory data needed to be generated to prove a material's worth. In storage, factors degrading the tank are moisture, ozone, and abrasion as the tank is shifted around in the box. In service, the major factors affecting the tank are ultraviolet light and abrasion from movement while the tank is being set up. This report deals with the abrasion of the urethane in a stressed condition caused by folding the tank for storage or dragging an empty tank over the ground in such a way as to abrade the corners.

SECTION II. INVESTIGATION

Current specifications for collapsible tanks do not include an abrasion requirement because the standard tests used in the rubber industry are unreliable indicators of field performance. The mode of abrasion failure in the field is *stressed abrasion*. Stressed abrasion occurs when the outer coating of the material is under a tensile load induced by a fold or a compound fold of the tank.

MECHANICS OF ABRASION

Abrasion is defined as "the wear of a material due to the effect of friction."* When two materials come into contact with each other, they plastically deform and some atoms from the material come into close enough proximity of each other to form atomic bonds. In the formula

$$F = f*N,$$

Where F = Friction
N = Normal Force
f = coefficient of friction

The coefficient of friction is caused by these atomic bonds. This is the reason that the coefficient of static friction is higher than the coefficient of sliding friction—more bonds form when a body is at rest. Wear caused by atomic bonding is known as *adhesive wear.* Another type of wear, *mechanical abrasion*, is caused by a rough surface cutting into a material and tearing pieces out.

In urethanes, adhesive abrasion occurs when the adhesive force between adjoining materials is stronger than the chemical bond in the polymer chain. When an atom is removed through this process, the chain is weakened and wear occurs more rapidly. When a urethane is under a tensile stress, the chemical bonds are spread out and adhesive wear can occur with less of an atomic force applied (see Figures 1 and 2). For the same reason, mechanical friction occurs more readily when the urethane is under a tensile stress.

TEST APPARATUS

For this test, an apparatus was designed and made that placed the urethane under a constant and reproducible stress. Because putting material into a compound fold configuration would make the test dependent on the thickness of the material, this solution was unacceptable. Instead, a Taber Abrader was modified to accept a platten that would be adjustable for height in the center with a ring on the outside edge to clamp the material down (Figure 3). In use, the material would be placed

*McClintock, Frank A. and Argon, Ali S., *Mechanical Behavior of Materials*, Addison-Wesley Publication Company, Reading MA, 1966.

on the platten with the center ring in the down position. After the material is secured to the outer ring, the center section would be raised to a height of 1/4 inch. The vertical distance between the edge of the center section and the outer ring is 1/2 inch, giving the material a bend of -30° from the horizontal position (Figure 4). A ceramic abrader wheel (Figure 3) Calibrade H-18 manufactured by Taber Instruments was mounted onto a swivel arm so that the edge of the wheel would ride on the crease created by the platten at an angle of 10° from the horizontal plane. The sample was then subjected to a number of cycles sufficient to expose the base fabric. The ceramic wheel was resurfaced every 500 cycles to minimize error associated with clogging or a worn surface. A standard Taber Abrader was used to gather information about the abrasion characteristics of an unstressed sample from each material.

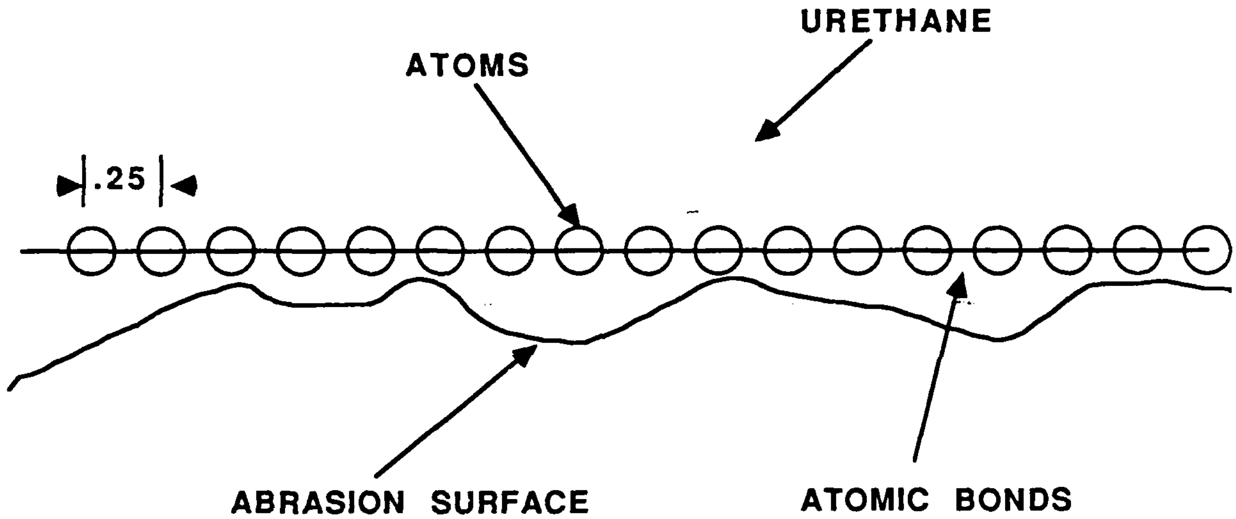

Figure 1. Urethane Unstressed

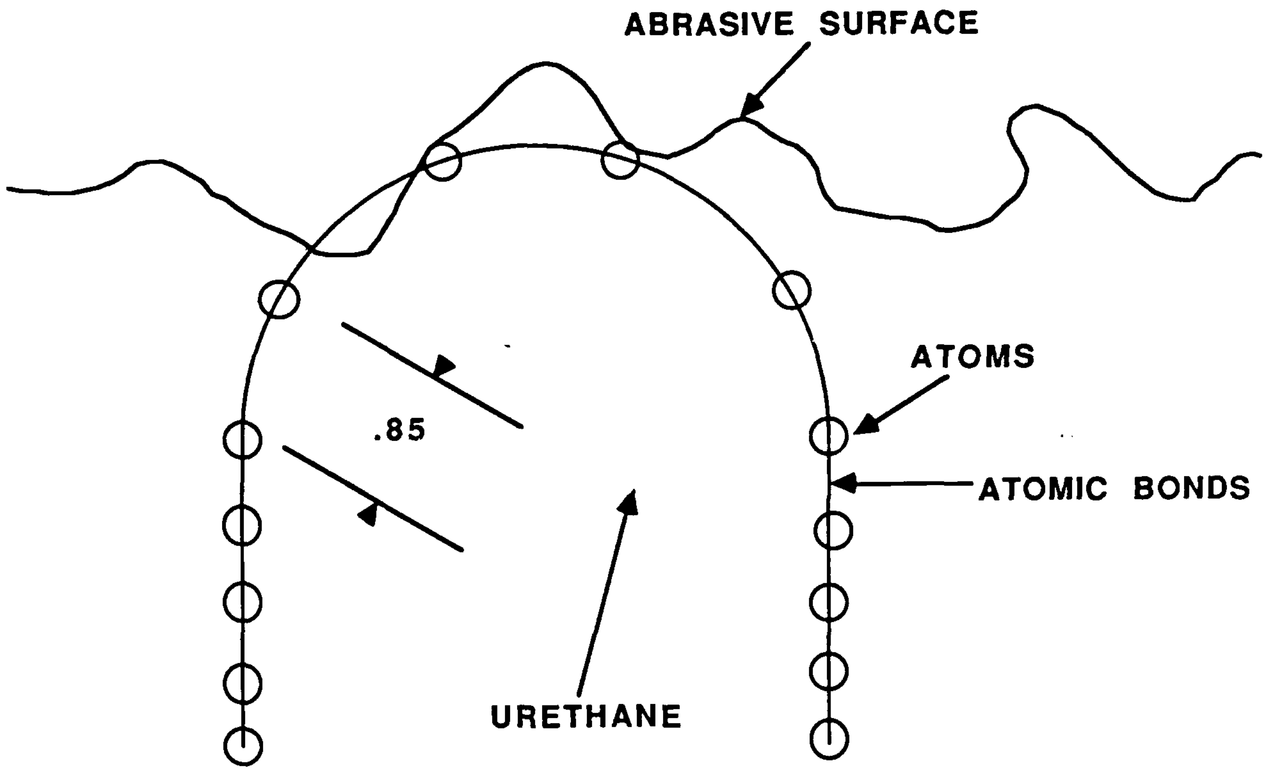

Figure 2. Urethane Stressed

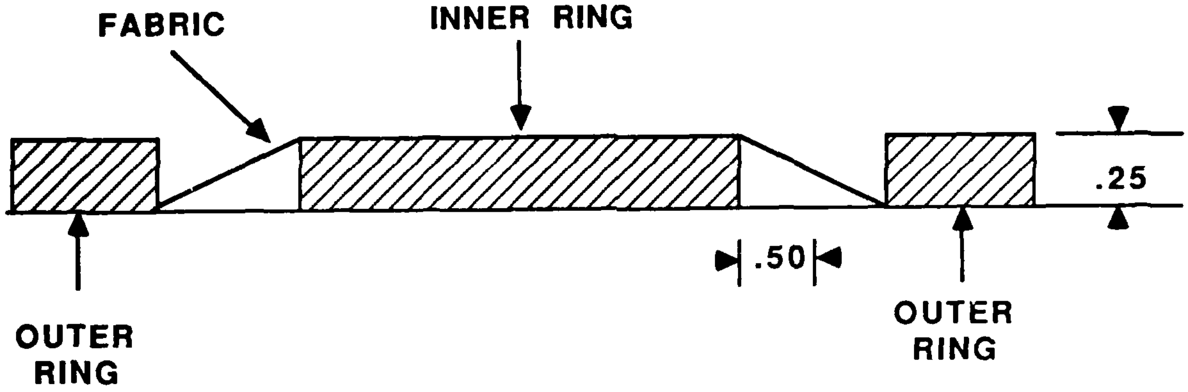

Figure 3. Stressed Abrasion Tester

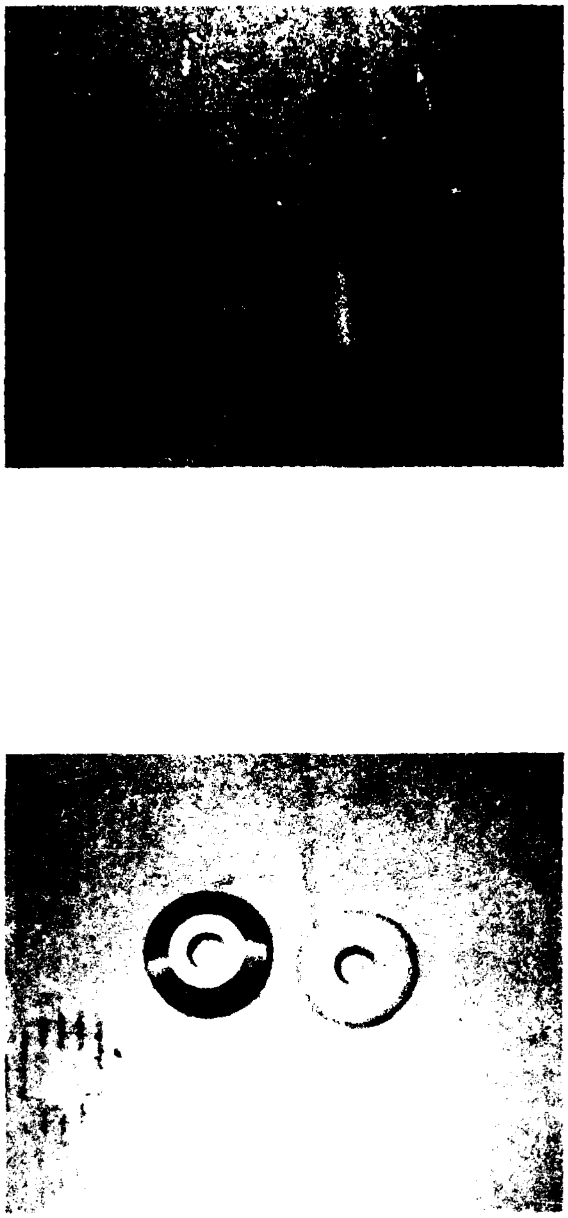

Figure 4. Taber Wheels

MATERIALS

Four different materials were chosen to demonstrate that a stressed fabric abrasion test is possible. All of the materials are either now being used in the manufacture of collapsible tanks or are proposed materials.

Material #1 is a nitrile coated nylon 0.68mm thick currently being used to manufacture a lightweight water tank.

Material #2 is a thermoplastic urethane coated nylon 1.10mm thick currently being used to manufacture pillow tanks.

Material #3 is a different thermoplastic urethane coated nylon that is 1.22mm thick. It has been recommended as an alternate material in the ma .ufacture of pillow tanks.

Material #4 is not a urethane, and the chemical composition is unknown. It is a thermoplastic coating material over a polyester fabric currently being considered for use in berm-liner procurements.

Each of these materials was tested in both the stressed and the unstressed configuration. The results are tabulated in the following table.

ABRASION TO FABRIC EXPOSURE

MATERIAL	TABER CYCLES	STRESS CYCLES	STRESSED/ TABER RATIO	COATING THICKNESS MM	CYCLES/MM UNSTRESSED	CYCLES/MM STRESSED
#1	1,000	129	7.75	0.254	3,937	508
#2	100,000*	1,978	50.65*	3.048	32,808*	
#3	100,000*	2,046	48.88*	3.046	32,830*	672
#4	1,100	600	18.33	3.302	333	182

* Estimated minimum

SECTION III. DISCUSSION

Because of the difference in the thickness of the materials, a direct comparison of the absolute values of the data was meaningless. Taking the ratio of the Taber results over the stressed abrasion results yielded a dimensionless number used to directly compare the fabrics to one another. The thickness of each coating material was also determined and the cycles/mm were calculated for both the stressed and unstressed abrasion conditions.

The low ratio for material #1 (7.75) was not unexpected because nitriles do not seem to abrade more on the creases in the field. Also, the Taber Abrader results for this material were quite low.

The 100,000 cycle estimate for the Taber Abrader on materials #2 and #3 was necessary because all the wear on these samples occurred within the first 5,000 cycles. The wheels on the Taber Abrader were cleaned, but the abrasion did not increase.

The very high ratios in the urethane samples showed that the materials were very susceptible to stress abrasion and that normal unstressed abrasion tests would show these materials to be very good at abrasion resistance. The cycles/mm in the stressed configuration showed that urethanes did not exhibit a better stress abrasion resistance than nitrile when subjected to stress. In the field, the urethane tanks would be more susceptible to abrasion failure at the seams.

The low value for material #4 (18.33) demonstrated that the urethanes did not succumb to stressed abrasion because of the inherent nature of thermoplastics. This material, a thermoplastic, did not exhibit the drastic change in abrasion due to stress that the urethanes exhibited.

SECTION IV. CONCLUSIONS

The test apparatus looks very promising. It showed that urethanes are inherently susceptible to stress abrasion and that the test method as designed will work. The apparatus needs to be modified to permit the use of two serrated Taber wheels instead of the one ceramic wheel. This would eliminate some of the error inherent in the machine due to the fact that the ceramic wheel clogs.

Field data must be collected and compared to the laboratory results of all the tanks in the Army's inventory so a minimum ratio number can be established for inclusion into the pertinent military specifications. This is becoming more and more important as the military continues to request tanks having a longer life.

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